Nationaal Lucht- en Ruimtevaartlaboratorium
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Executive summary

Variable Uncertainty: Scenario Design for Training Adaptive and Flexible Skills


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Problem area
Crisis management requires skills that are adaptable and creative to address the rapidly changing and uncertain nature of the crisis. It is therefore essential that training systems are developed to include the variable and uncertain nature of the environment within the training scenario.

Description of work
Within the European Union CRISIS research project, the Variable Uncertainty Framework (VUF) has been developed to address these challenges in training scenario design for an interactive simulated training environment. The VUF is intended to bring together three important aspects of crises that can be used to control the training scenario: situational complexity, the number of events occurring simultaneously and the randomness of these events.

Results and conclusions
This paper illustrates the VUF and describes the way that it complements the instructional design principles for complex skills training using the Four Component Instructional Design (4C/ID) method as a basis. The VUF offers instructors and training designers an accessible way of controlling the variability and complexity in training scenario design within a simulated training environment.

Applicability
The analysis described in this paper applies to the principles for training scenario design in a simulated training system. It is illustrated in terms of crisis management where the emphasis is on training complex skills so that they are adaptable to a variety of crisis situations.
The research leading to these results has received funding from the European Union Seventh Framework Program (FP7/2007-2013) under grant agreement no. FP7-242474.

This report is based on a presentation to be held at the European Conference on Cognitive Ergonomics 2011 – Designing Collaborative Activities, Rostock, Germany, August 24-26, 2011.

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Abstract

Motivation – Today's training systems for crisis management (CM) largely focus on technical and procedural skills. However the dynamic and unpredictable nature of a crisis also requires skills that are flexible, adaptive and creative. Training systems enforce limitations on the freedom of interaction the trainee has compared with the real world, thereby limiting their effectiveness for real world emergencies. Furthermore, the training scenarios are often played out in a linear and rigid manner, limiting the ability to train skills such as adapting to the on-going situation and being flexible in an uncertain and variable environment.
Research approach – The Variable Uncertainty Framework (VUF) has been developed as part of a European project (CRISIS) developing an interactive simulated Virtual Reality (VR) environment for training CM to address some of the challenges faced in training scenario design today. The principles from software systems design have been compared to those of instructional design to develop a framework that can be applied in this project.
Findings/Design – The VUF brings together three important dimensions of real-world emergencies that can be manipulated and controlled in virtual training environments:
(1) situational complexity, (2) the number of events occurring simultaneously, and (3) the randomness of these events. By controlling these three dimensions in the training environment, an instructor can design scenarios that are either basic drill oriented, or advanced scenarios where events are complex and combined in un-predictable ways.
Take away message – The VUF is illustrated as a method of achieving the variability and complexity in the training scenario design. It offers an accessible method for instructors to design and adapt training scenarios to optimise the training effectiveness.

Keywords
Training Design, Crisis Management, Instructional Design, Complex Skills, Simulation,

Contents

1 Introduction

Crisis management (CM) operations take place in multi-organisation teams that respond to a single, or series of, event(s) that are initially outside their control. It is possible for these teams to prepare their response in general terms, but in practice every event will have unique aspects that make full preparation difficult to achieve. Therefore, key aspects of crisis management training include teamwork, dealing with the situation in a flexible manner, and increasing the skill of adaptive thinking (Raybourn, 2007). These skills involve responding to what is actually taking place and adapting to the situation as is required.

Crisis management tasks vary depending on the role of the team member within the crisis management team. For commanders and staff at the command centre the cognitive elements of their activities are an important part of the command and coordination tasks, likewise for the team leaders or coordinators at the incident scene (Burke, 1997). However, there is a need for improved access to training for the entire crisis management team, not only for the first responders.

CM training usually consists of partial or full-scale exercises. As Auf der Heide (1989) points out, is it necessary to train often as crises differ from every-day, routine emergencies. However, live exercises involving multiple agencies are costly in terms of time and funding, making digital technology an important new source for training. Also, training systems often have limitations to train adaptive behaviour as they are context-specific and anchored to the technical environment (Dekker et al., 2008). Training scenarios have the problem of being time consuming to create, and are often played out in a linear and rigid manner. There is a need for CM training that prepares for flexible and adaptive skills, in particular cognitive and team skills.

The 4C/ID or Four Component Instructional Design model (Van Merriënboer, 1997; Van Merriënboer & Kirschner, 2007) provides guidance on how training should be designed to capture the complexity and variability that occurs in real-world crises and emergencies. We will provide a brief review of this in the next section.

However, further guidance is required to inform system developers how these real world factors of complexity and variability can be designed and implemented into the software of simulation systems used for training of crisis management in virtual training environments. Motivated by this need, we present VUF, the Variable Uncertainty Framework (Wong, Rankin, and Rooney, 2011). In the VUF, the operational concepts of variability and complexity are represented as three dimensions that enable a more direct translation of these concepts into software design: situational complexity; the number of events occurring simultaneously; and the randomness of these events occurring. We then explain how the VUF is used to guide (i) the design of software functions needed to support instructors control variability and uncertainty when designing

training scenarios, and (ii) how the training simulation software based on the VUF can create and control the simulation scenarios for acquiring and maintaining adaptive and flexible skills.

2 Crisis Management Training Scenario Design: Applying 4C/ID

Crisis management requires response personnel to be able to respond to unexpected situations. It is not possible to predict the exact nature of the crisis in advance, since a number of factors influence the evolving scenario, such as the scale, type, location, and weather conditions. Also, the crisis management teams and materials available to them will not be identical for each crisis. There may be relatively inexperienced team members, collaboration with teams from other regions, and there may be insufficient stock of materials, or materials may break. Therefore the training of crisis management personnel should include various types of adaptability.

High performance professional jobs, such as crisis management, require a set of complex skills. In this context complex skills are defined as an integrated combination of skills of various natures (e.g. procedural skills, social skills, technical skills). Van Merriënboer (1997) suggests four key components to the learning process for complex skills: training tasks (whole tasks), supportive information, just-in-time information and part-task practice, described in the Four-Component Instructional Design model (4C/ID). Two instructional principles associated with whole-task training are applied to ensure that the trained skills can transfer to a wide variety of real situations: *variability factors* and *complexity factors* (van der Pal et al. 2002; van der Pal et al., 2003; Van Merriënboer & Kirchner, 2007). Variability factors are used to create variation between exercises, and complexity factors are used to modify the difficulty of exercises. These are defined in the context of 4C/ID as:

Variability factors are (operational) task conditions, such as certain environmental aspects (e.g. materials, buildings) that will differ in each crisis but are known for not substantially increasing or decreasing the difficulty of the task.

Complexity factors will vary among the crises as well, but they do increase or decrease the difficulty of the task. For example day versus night, the experience level of team members, road conditions (wet/dry), system failures, number of incidents occurring simultaneously, size of incident, etc.

2.1 Instructional Design Principles

When designing for training complex cognitive skills, both variability factors as well as complexity factors are vital to create adaptability of the crisis management skills. Complexity factors can be used in the design of whole task training to ensure an optimal cognitive load to

trainees along the learning process. Initial training tasks can be designed in a whole task fashion when all or most complexity factors are set to their easiest levels: e.g., small incident, other team members are highly experienced, weather and visibility is good, road conditions are fine (dry), no system failures. Such easy settings will be difficult enough for novices to apply the procedures learned within the full crisis management environment. Variation within the same difficulty class of training tasks is required to ensure the skills trained are adaptive and flexible. To illustrate, the location of a fire may not be either more or less difficult to the fire fighter, but if the location is always the same in training, the need for proper communication and decision making about the location is no longer there and the training value is drastically reduced. Training becomes routine on aspects where it should not be. It is therefore important to include variation, even in simple training.

Once the skill level of the trainees increases, or they are more experienced, the complexity factor can be set to higher levels. In addition, variation in the training is ensured by changing the settings of variability factors. In this way, the conditions to create or maintain a robust and adaptive set of skills are met.

2.2 Application in Crisis Management Training

Instructors attempt to re-create the complexity and variation that can be expected in real-world crises by ensuring a high level of complexity within an exercise, and high variability over exercises. While it can be considered that many of the personnel involved in crisis management teams may be very well trained in local tasks (e.g. individual tasks, or elements of a crisis), their introduction to the crisis management team can still be treated as novel training for them (with respect to co-ordinator's competencies). It is considered necessary, even for these experienced emergency service team leaders, to introduce the crisis management environment at a simple level increasing the complexity level as the trainee develops. This process allows the trainees to familiarise themselves and build up the skills that are specific to crisis management. Initially the complexity level of the training environment is therefore kept at a consistent level, while the variability is modified. As the training proceeds, the complexity level is increased to build a more robust level of performance and adaptability.

The predictability of the crisis as it develops also affects the ease of learning, and the complexity of the training scenario. A trainee might learn to predict the sequence of the events in a scenario, or build incorrect relationships between them. Therefore, it is desirable to maintain a basic level of variability for the trainee. A low variability drill (a part-task practice) however, may be needed to acquire particular rote or automated skills or procedures for task elements that require thoughtless action (using code words for example). Drill practice will also be required at certain times for experienced professionals to refrain from skills decay.

To summarise, when designing scenarios for crisis management, the 4C/ID model suggests considering a series of whole task exercises, which should sequence from simple to complex using the complexity factors to design the training tasks for novices. There should be variation between the training tasks, especially for training tasks that use the same complexity factors. Variability factors can be applied to ensure that variation. For tasks that require routine action, e.g., using equipment and software, part task practice may be required. The 4C/ID model refers to variables of crisis management that relate to competencies (both generic and task specific), aspects of task and context. However, the translation to simulation environments is not dealt with explicitly.

3 Variable Uncertainty Framework

The *Variable Uncertainty Framework* (VUF) (Wong, Rankin, & Rooney, 2011) is proposed to describe the design and control of the exercise scenarios in the simulated environment system. The VUF was conceived as a method of assisting the system developers in the CRISIS project in breaking down the aspects of the incidents and accidents that would be used to design and control the training. An analysis of the aspects in a situation that affect the difficulty, complexity and variability, and identifying aspects that could be controlled in the training environment lead to the definition of the VUF dimensions.

The VUF complements training design models such as 4C/ID, as it was developed with the purpose of specifying how the software of the simulated training environment should be designed in order to manage the variability and complexity of the training exercise scenarios. This is achieved by configuring three key aspects of the training scenario design, as illustrated in Figure 1:

- the number of events or sub-events occurring
- the randomness of the events
- the situational complexity around the events

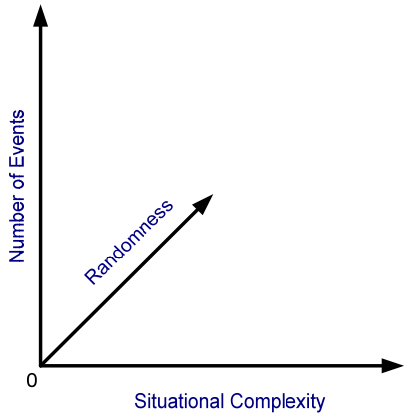

Figure 1 Controlling the variability & complexity in scenarios

The framework is applied to configure the events that make up the exercise scenario, determining how and when each event occurs. This provides the opportunity to design exercise scenarios where the complexity, variability and uncertainty can be adjusted to suit a variety of training objectives using three dimensions (Wong, Rankin & Rooney, forthcoming):

(1) *the number of events or sub-events occurring*. Events during the exercise scenario, such as a fire occurring in aircraft wreckage, can be broken down into sub-events. Sub-events are events that occur as a consequence of the main event, such as the aircraft structure collapsing. These can be adjusted for their unpredictability and/or complexity. By increasing or decreasing the number of these sub-events (and events) occurring simultaneously, tightly spaced, or loosely spaced, an instructor can make the situation more challenging, or less challenging.

(2) *the randomness of the events*. This reflects the degree to which the trainee(s) are able to expect, or predict, events, sub-events and the sequence in which they occur during the training exercise scenario. By creating a window around the on-set time of an event (or sub-event), an instructor can manage the uncertainty of an event occurring by varying the window of time when the event starts. A small window would reflect a higher level of certainty, while a large window would reflect a higher level of uncertainty. This is designed to affect how random, or unpredictable, the event is for the trainee, while being controllable by the instructor.

(3) *the situational complexity around the events*. The operational aspects of the training exercise scenario that are associated with the event situation can be varied in complexity by configuring the attributes of the objects present in a situation. For example, the ‘size’ attribute of a fire object can be increased from a small to a large fire, or its ‘intensity’ attribute configured to be a ‘gentle fire’ or ‘fierce fire’. In addition, situational complexity can be increased by increasing the dependencies between events. Triggers or threshold values can be set so that, for example, if a fire event takes too long to be attended to, it can trigger downstream consequences such as

secondary explosions that lead to more casualties. These triggers can also be assigned variable windows of randomness.

3.1 Linking VUF and Instructional Design

These dimensions can be considered in terms of 4C/ID training design. The *number of events*, which is considered as a complexity factor in the 4C/ID training design, can be used to control the difficulty of the exercise. The difficulty is intended to increase with the number of sub-events leading from the main events that occur simultaneously. The *randomness of events* is, in terms of the 4C/ID training design, a variability factor. It is not intended to increase the difficulty level, but to ensure unpredictability in the training. 4C/ID suggests that variation between exercises should be ensured and VUF offers a particular approach to achieve this. The *situational complexity around the events* of the VUF is considered as environment-related complexity factors in terms of 4C/ID. In this way the 4C/ID complements the VUF in training scenario design by providing the mechanism for configuring human related complexity factors associated with personal or team factors (e.g. fatigue, lack of knowledge, fitness, and inexperienced team members) into the design of the simulation.

This concept, linking the VUF and 4C/ID in terms of wider exercise design, provides us with simulation design ranges for different types of exercises (As illustrated by the three exercise types in Figure 2). A specific example of this is given in the next section. For example, simple well-understood, single-sub-event situation that is tightly controlled, is good at providing trainees with practice in particular aspects of crisis management, such as in part-task practices or drill-type exercises.

An alternative type of exercise involves performing the full scope of CM tasks, but having to deal with one sub-event at a time, and a relatively low situational complexity. Then training exercises become more realistic when the unpredictability of the events is relatively high for the

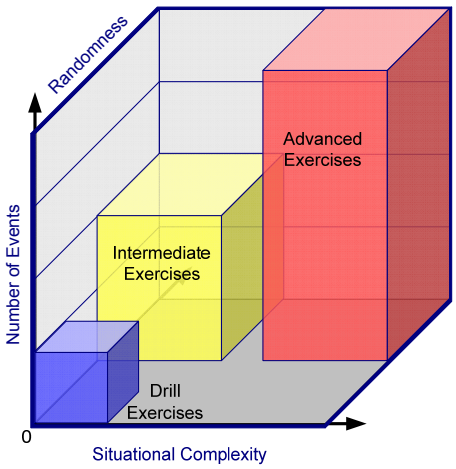

Figure 2 Variability Uncertainty Framework illustrating three exercise design ranges

participants. This type of exercise demands the full set of CM competencies, though not at a high proficiency level. As such these exercises provide a whole-task exercise for novice to intermediate experienced professionals. Finally, by increasing the number of events that are presented simultaneously, with high situational complexity and unpredictability, situations that require an advanced level of expertise are created..

The VUF forms a guideline for instructors to group the individual factors of the exercise scenario that are available to adjust the training into three main dimensions. In terms of the design of a simulation training system, this also provides the designers and developers with a design target for the instructor's control of the exercise design, planning, creation and running, thereby playing a role in the system design. Together, the VUF is intended as a basis to achieve a configurable simulated training environment that can be applied to achieve the elements of variability and complexity in the training exercises that lead to effective crisis management training.

4 Linking VUF and 4C/ID: An Example

The following task factors can be considered as some of the situational complexity factors that would be available in designing a training exercise for a crisis management team around an aircraft accident scenario:

(a) number of casualties;

(b) size of aircraft;

(c) weather conditions: wind effects on the fire, weather influence on the casualties, visibility, wet/dry;

(d) time of day;

(e) accident location: within the airport area, geography, ease of access;

(f) number of responders available; and

(g) amount of damage: size of the fire, number of wreckage locations.

The variability (4C/ID) of the exercise can be determined by the randomness of the events (VUF). In addition, the variability can also be affected by other factors in the scenario design. Examples of these are contextual environmental aspects, which could include the location within the airport, sequence of events, aircraft model, buildings around the accident site and the location of the casualties within the wreckage. These aspects can be varied without affecting the difficulty level of the exercise. However, certain factors may affect the difficulty under certain contexts (e.g. a particular aircraft model may create additional difficulty), so the instructor must be aware of the effect on the full training scenario.

Within a training exercise that is focused on dealing with a major aircraft accident, there are a number of events included in the exercise design to address particular training objectives. Each of these events and associated training tasks affects the overall complexity for the exercise due to their interrelation, which can be described by the VUF. For example, an exercise that is made up of a high number of events, that are presented to the trainees at unpredictable moments during the exercise and that have a high situational complexity would represent an exercise for a high level of expertise. In contrast, an exercise could also be designed where the events that occur during the exercise may be expected by the trainees. However, the exercise includes a large number of sub-events that are sufficiently complex to promote the training tasks associated with the coordination between the trainees. In this case the exercise has been designed to target a particular sub-set of the training objectives for the crisis management team.

4.1 A Use Case

The application of the variability and complexity to design a training exercise around the variable uncertainty framework can be illustrated using the following example.

An instructor is designing a training exercise for the crisis management team at an international airport. This exercise will be carried out in their simulated training system, and will involve a representative from the four primary organisations in the response team. The aim of the exercise is to practice the command and coordination procedures for the team. All of the trainees are experienced in their own field, though one trainee – the fire service team leader – is new to the crisis management team. The other three team leaders have been involved in previous response team training exercises, and one has been involved in a real aircraft accident response. Given the experience of the trainees, and the overall objective of the exercise, the exercise is intended to have a relatively high complexity level, while not overloading the fire service team leader.

In this example it is desirable to have a relatively high variability for all of the trainees, given their experience and the training objectives of the exercise scenario. Since they are experienced with their own specific tasks, and the emphasis of the exercise is the command and coordination of the wider team, the elements of the scenario that are specific to their role can be varied. For example, the wreckage of the aircraft is in a new location on the airfield at an under-used runway due to construction work, and the fire at the accident site is in an unexpected location of the wreckage, caused by cargo rather than fuel, say. Therefore the team members are not familiar with the specific details of the routes to the wreckage, the geography or weather influences in that area. However, these factors do not significantly increase the difficulty of the exercise for the trainees. They are intended only as a variation of the exercise in comparison with other training exercises that they have experienced.

Given the relatively specific responsibilities that each trainee has within their organisation, this allows the instructor to tailor certain elements of the exercise for them, without affecting the exercise for the other trainees. The activities in the exercise that relate to the control and extinguishing of the fire, the rescue of the casualties and structural safety of the scene are the specific responsibility of the fire service team leader. The activities that relate to the security of the scene and controlling access to the scene are the responsibility of the police service. Having a large number of people trying to get close to the scene of the accident, and many separate media representatives asking for interviews only affects the police service trainee in this example, it does not need to affect the exercise for the fire and medical service trainees. Activities that relate to the overall coordination of the accident response need to be considered by all of the team leaders.

The instructor can adjust some complexity factors for the trainee during the exercise design. The fire service team leader will be dealing with a small team, with simple tasks and no complicated situational aspects – so the wind will not affect the fire significantly, the access routes to the wreckage will be easy to navigate for the fire vehicles, all of the equipment will be available and the casualties are easily accessible or have been able to exit the wreckage themselves. There will also only be two additional fire events during the exercise that need to be controlled, though they will occur at unpredictable times. The fire service trainee is still required to be fully involved in the coordination meetings and tasks for the command and coordination team. This introduces the trainee to the aspects that are involved with the crisis management team, but at a simple level of complexity. This puts the training exercise in the "intermediate" region of the VUF for the fire service team lead. This is illustrated in Figure 3.

The other team leaders, such as for the medical and police teams, will be dealing with a large

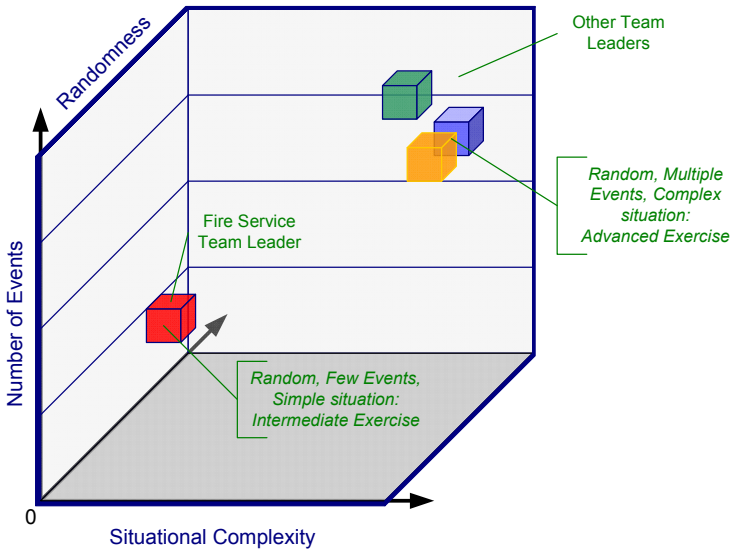

Figure 3 Example of the variable uncertainty framework elements of a training scenario

number of casualties, a variety of different injury severities, the location of the crash site is close to a publicly accessible area so there is easy access for bystanders and the media. These are aspects of this aircraft accident scenario that are designed to increase the complexity of their tasks, increase the number of events that they must deal with, and increase the unpredictability of the exercise for them, thus placing the exercise in the "advanced" region of the VUF.

The concept behind the VUF is to identify the factors that are available to the instructor during the training exercise design, and the effects that these have on the complexity of a single exercise for the trainees. In addition it enables exercises to be varied easily between training sessions, thus overcoming the difficulty of designing multiple exercises with sufficient variation for training principles.

5 Conclusion

The variable uncertainty framework (VUF) has been developed as part of the FP7 CRISIS project to offer a basis for the design of the training scenarios in a simulated training environment. It is intended to translate the principles of instructional training design into the training exercise scenarios in the simulated environment. The VUF offers an accessible method for scenario design that allows instructors to adapt the variability and complexity factors in the training design and control the cognitive learning effect of the tasks both prior to and during the training exercise in the simulated environment.

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